Chapter II

Literature Review

2.1 The role of coffee production in DakLak's economy

Coffee, one of the major products in DakLak, plays a very important role in the socioeconomic development of the province. It contributes to about 60 percent of the total GDP and 85 percent of the total value of agro-forestry products and provides employment to about two-third population of DakLak. So any negative impacts on coffee production and price often seriously affect DakLak' s economy and income of farmers, who depend on coffee product as the main source of family income (Sung, 1999).

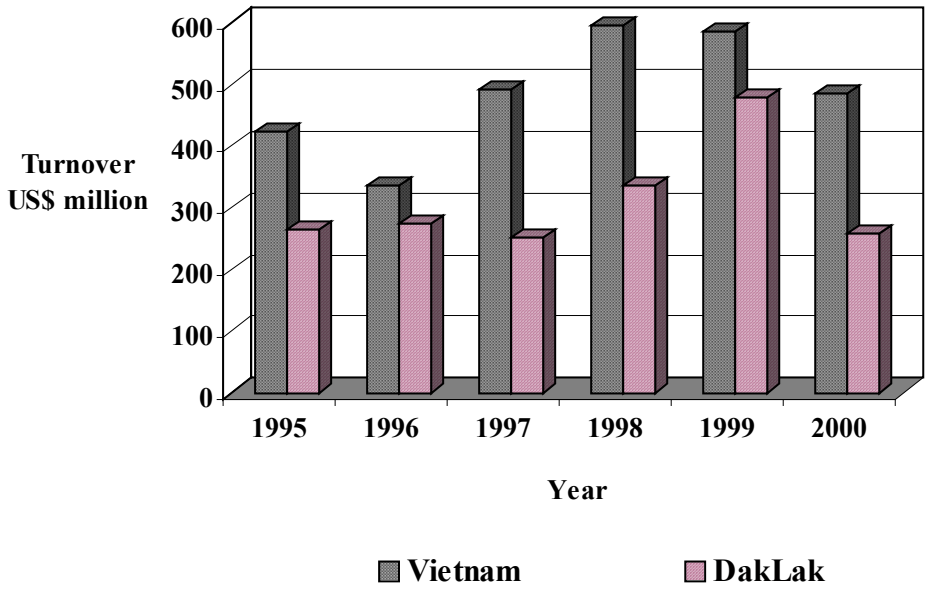

Figure 1. Turnover from coffee export of Vietnam and DakLak

Source: DakLak Trade and Tourist Department, 2002.

2.2 The concepts of cropping systems and sustainable agricultural systems

According to Andrew and Kassam (1976), intercropping is to grow two or more crops simultaneously on the same field. Crop intensification is in both the time and the space dimensions. There is intercrop competition during all or part of growth. Farmers manage more than one crop at a time in the same field. In contrast, monoculture is the repetitive growing of the same sole crop on the same land.

So far, there are several concepts of what constitutes sustainability. With regard to agricultural systems, it is important to define for what purposes of sustainable agricultural system to be used. It may, therefore, be defined as:

"A system in which the farmer continuously increases productivity at levels that are economically viable, ecologically sound, and culturally acceptable, through the efficient management of resources and orchestration of inputs in numbers, quantities, qualities, sequences and timing, with minimum damage to the environment and danger to human life" (Okigbo, 1991).

Sustainability means the capacity of a system to maintain its productivity/profitability at a satisfaction level over along or indefinite time period regardless of year to year fluctuations (McConnell *et al.*, 1997).

Sustainability and sustainable coffee production according to Rice *et al.* (1999) are:

Sustainability is the ability of any system to continue. Sustainable agriculture is the production of agricultural products to continue by building soil health and protecting the ecological environment so that production can continue.

Sustainable coffee is produced on a farm with a high biological diversity and low chemical inputs. It conserves resources, protects the environment, produces efficiently, competes commercially and enhances quality of life for farmers and society as a whole.

Coffee production regimes which preserve biodiversity and habitat integrity as well as diminish the negative impact that other methods of coffee cultivation can have on the health and economic security of coffee producers.

Sustainable is defined in terms of the producer and in terms of the environment. Sustainable coffee means coffee producers are able to make a living from coffee. Secondly the coffee production should not negatively impact the environment

Sustainability is the ability to produce a product without damaging the environment and to leave it with the ability to produce for the next generation. For coffee, this means incorporating organic, habitat conservation, and fair trade.

Sustainable coffee is the umbrella term that covers organic, fair trade, and the shade/sun debate, each of which is an important issue on its own. Sustainable means securing production for the next generations: will there be coffee, will the environment be cared for, will the people be paid fairly.

Sustainable coffee has to start with the health of the land. If it's not organic it's not sustainable.

Sustainable development cannot be defined within a static framework: it is a dynamic process which tends to embody principles and guidelines for action. Sustainable development refers to development which is more equitable on the social, economic, ecological, political, spatial, and cultural levels (Rice *et al.*, 1999).

2.3 Intercropping coffee farms and its roles

Coffee has a significant impact on the economy of over forty producing countries. In value, it is the second only to oil in terms of international trade and surpasses sugar, rice and wheat as the major agricultural commodity. Over twenty million people are employed in growing, distributing and retailing coffee world-wide. Robusta is grown in West Africa, Brazil and Vietnam that are the most dominant

growing areas. Robusta currently represents around 30 percent of world (Nhan *et al.*, 1999).

Coffee is traditionally grown as an understory plant, consistent with its shade tolerant nature. During the history of cultivation, most of the farmers have changed to grow coffee in full sun (monoculture) to improve yields and to reduce the negative affects of diseases like fungal infection, however, widespread transformation of this practice have been taken place for the last two decades (Perfecto *et al.*, 1996). This conversion, to using shadeless varieties of coffee and high amounts of chemical fertilizers, is part of the "technification" trend of the last two decades. This shift in production methods carries with it a wide array of concerns, including loss of biodiversity, habitat fragmentation, pesticide poisoning, soil degradation and erosion, and economic resilience of small-scale farmers (Bau, 1997).

Meanwhile, shade coffee or intercropping coffee with cash trees and fruit trees, offers substantial advantages over coffee cultured in monoculture. Over canopy trees protect the relatively sensitive coffee bush from harsh wind, excessive light and soil erosion, and they moderate the temperature and microclimate on coffee farm. Predation poses little threat to covered coffee, and nutrient deficiency is seldom a serious problem. Furthermore, in some regions in the world such as America, Africa, and Asia, intercropping plantations support as biodiversity as to that in some rain forests, and provide alternative crops when demand for coffee falls. Slower maturation and lower yields can be considered as the major disadvantages (Nghi *et al.*, 1996).

Mono-coffee farms, also known as modern or mono-plantations, require more maintenance, hence are not economically viable when output falls below a fairly high threshold. Also, sun plantations typically experience greater run-off and nutrient leaching and remain productive for only one-third to one-half as long as comparable shaded plantations (Perfecto *et al.*, 1996). Other characteristics include low biodiversity and high inputs of agrochemical.

The socioeconomic aspects of monocropping against intercropping coffee culture are carefully considered. Intercropping coffee contributes to diversity of species

including some small animal and birds. Normally, farmers have little or without incentive to be recognized the roles of shade coffee. In some recent, the coffee scientists have begun to educate farmers and consumers about the benefits of intercropping coffee and some offer them incentives to compensate for low yields (Sung, 1997).

Table1. Characteristics of shade and sun farms

Items	Shade farm	Sun farm
Yield	Lower (25-40%)	Higher
Plants/hectare	Low	High
Kg/hectare/year	Medium	High
Lifetime of plants	24–30 years	12–15 years
Flavor	Less bitter	More bitter
Who produces?	Small-scale	Large-scale
Weeding	Lower	Higher
Chemical fertilizers	Lower	Higher
Pesticides	Lower	Higher
Irrigation	Lower	Higher
Soil erosion	Lower	Higher
Soil acidification	Lower	Higher
Toxic run-off	Lower	Higher

Source: Gorsline: URL 1.

Gorsline (URL) had come up with a conclusion when studied many characteristics in two coffee patterns. He found that trees in the intercropping farms provided several necessities to the organic coffee farm, among them leaf litter (which acts as a fertilizer), resident wildlife species that control pests, and the retention of moisture. On the other hand, the shade coffee farm or intercropping farm, although,

gave lower yield than that of sun farm. But the intercropping farmers did not depend so much on external inputs. This gave the potential for a long-term production of small-scale farmers in coffee production (Table1).

2.4 Intercropping in relation with soil protection

Soil erosion is a major concern in agriculture, that leads to thin or/and infertile soils. Thereafter crop yields will be reduced and shorten the lives of perennial crops. Erosion of the most biologically active fraction of the soil profile is greater in exposed than coffee intercropping plantations (Ataroff and Monasterio, 1997). However, this disparity was temporary following establishment of the technified plantation and by the 9^{th} and 10^{th} years reduced. Second to the establishment of a plantation, the most important cause of erosion is human disturbance, which occurs more routinely in sun plantations. Moreover, sun plants age more rapidly than shade grown stock and must be replaced more often, specifically at about 6 versus 30 year intervals, respectively (Ataroff and Monasterio, 1997). In fact, this rather extreme estimate fails to consider the natural regeneration of the soil.

Weeds and erosion generally do not cause problems on traditional coffee farms (intercropping farms). Leaf litter forms a thick carpet of mulch, reducing evaporation, protecting the soil from erosion, and suppressing weeds. Also, the protective canopy buffers the soil from desiccating winds and the erosive forces of rain. The same can not be said for modernized coffee farms. Coffee is cultivated in the central highlands with elevation of 500 to 1000 meters above sea level, most serious problem is water runoff, that leads to loss of soil and fertilizers applied. It eventually leads to the reduction of productivity and increase of expenditures on fertilizer to maintain productivity. However, some of simple methods like intercropping, contour lines of green manure trees, and grass strips not only reduce soil erosion, soil degradation but also increase soil fertility in coffee farms at unproductive and productive periods (Truc, 1998).

2.5 Shade trees as a source of organic matter and nutrients

Loan *et al.* (1996) in his research about the existing residues on intercropping coffee indicated that, total residue from pruning shade trees and coffee trees, fallen leaves, grass on and surrounding farm can be gained to 25 tons and 21 tons of fresh weight per hectare for coffee planted on basaltic and granite soils, respectively. He also found that with 5 to 10 tons of residues application per year was able to create a considerable nutrient to meet the requirement of coffee trees, leading to reducing amount of macro-nutrients application. In addition under this condition, the structure, basic physical properties, and chemical contents of soil were also positively improved.

Nitrogen is one of the major nutrient elements that limits coffee production. Bornemisza (1982) and Aranguren *et al.* (1982) estimated that legume-shaded plantations acquire substantial N through symbiotic fixation by the overstorey and mineralization of organic matter. They showed that N input from shade tree litterfall alone approximated to be 95 kg N per hectare per year. Fallen leaves from *Erythrina poeppigiana* and the debris provided by pollarding added up to 173 kg N per hectare per year depending on whether trees were trimmed (cut) one, two or three times a year, respectively (Russo and Budowski, 1986).

Application of 10 tons of crop residues of all intercropped trees in farm combination with 150 kg N per hectare increases the coffee yield up 30 percent in comparison with application of 200 kg N without residues incorporation in the monoculture coffee farms (Tu, 1995). To identify the optimal amount of phosphorus for coffee demand, it was showed that application of 75 kg P_2O_5 plus with 10 tons of organic matters of green manure trees and litterfall for one hectare of sun coffee a year had attained the same yield with application of 200 kg P_2O_5 without OM. Using fused magnesium phosphate and two times of application per year in May and August are suitable for coffee in upland (Lich, 1997).

The coffee researchers of Vietnam have concluded that major fertilizer dose for the highly intensified robusta coffee in the Central highlands of Vietnam is 300 N, 100

P_2O_5, and 300 K_2O for one hectare per year. The yields were sharply reduced if lack of one of the three major elements (Sung,1999). But the result from a long-term experiment in the same province, namely, effect of N, P, K fertilizers to robusta coffee showed that applying 400 N, 150 P_2O_5, and 400 K_2O per hectare of mono-coffee farm obtained the highest yield and gross return. These elements could be adversely affected if over or lower amount were applied (Y-Kanin *et al*., 2001).

2.6 Water competition in intercropping

Advocates for shade coffee recognize the potential for competition for water and nutrients in those systems. Thai (1997) found that most of the roots of shade coffee plants occupy the upper 50 cm of soils with well defined surface plates. Purseglove, (1968) and Cuenca *et al.* (1983), suggested relatively little opportunity to interact with typically deeper rooted overstorey trees. Canopy trees may improve the water relations of crops by hydraulic lift, although, this possibility has not yet attracted the attention of investigators. Kanechi *et al.* (1996) showed that water stress inhibits photosynthesis more in sun plants under laboratory conditions.

Researchers of Vietnam coffee research institute had discovered that the coffee crop was water-stressed over a six week-period during spring of December to January, that accelerated uniform flowering of the crop. That means at harvesting time, there was an optimum yield of premium grade red cherries with few of the lesser-value immature green or over-ripe black cherries. Close monitoring of sixteen sites within the 200 hectare plantation over a 10 month period, has helped to calculate the precise timing of a basin irrigation system to achieve even flowering, allowing just enough soil moisture to keep the crop alive without promoting growth (Bau, 1999).

Plentiful supply of water all year round except during the late stages of floral development (September-November) when a period of water stress can be used to manipulate flowering. Under-tree (basin) and overhead irrigation are the two popular methods that have been using in coffee production. But the under-tree method is preferred by the small-scale farmers. In Bhuthankad Estate, Coorg of India,

continuous irrigation to keep soil moisture not to fall below 50 percent field capacity has achieved high and stable yield in Robusta and the yield increase was found to be 51 to 58 percent over no irrigation. (Ramaiah, 1988)

Like many tropical flora, *Coffea* cultivars are sensitive to frost. Caramori *et al.* (1996) studied frost protection provided by *Mimosa scabrella* Benth. Leaf and air temperatures remained warm at night in traditional plots, and plants experienced less damage and produced higher yield in comparison to monoculture plantations in Mexico (Barradas *et al*., 1986 and Baggio *et al.*, 1997). Piché evaporation, soil temperature and vapor pressure deficits were also lower under shade trees. Overstorey trees also reduced wind speed below their canopies to create an advantage condition for cross-pollination of robusta coffee (Nghi *et al.,* 1996). A research on air temperature dynamic and wind speed in Phu Qui, Vietnam showed that: some days in the hot season the air temperature reached to 60^{o}C in monocoffee farms, while in intercropping coffee farms was 37 to 38^{o}C. In contrast, in the cold season air temperature was 3^{o}C below zero and 0^{o}C in monoculture and coffee intercropping farms, respectively (Nghi *et al.*, 1996). Therefore, coffee under intercropping farms suffered less stress than that of mono-farms.

2.7 Diseases and pests on farm

Insect pests and diseases damage coffee and reduce its yield, robbing the farmer of his profits. According to Uganda Coffee Development Authority (UCDA), there are some major insect pests and diseases, which can bring damages coffee. Coffee berry borers (*Hypothenemus hampei Ferr);* leaf miners (*Leucoptera spp);* leaf skeletoniser (*Epiplema dohertyi Warr); and* tailed caterpillar (*Epicampoptera andersoni Tams) are the species that often appear on the coffee gardens in Uganda.* Coffee leaf rust (*Hemilia vastatrix);* red blister disease (*Cercospora caffeicola);* fusarium die-back (*Fusarium stilboides); and* root rot or collar crack (*Armillaria mellae) are the key diseases of the coffee. Different species has different way to damage crop and and occur in different time and space. So understanding their characteristics, one can manage and control them in order to minimize losses of crop from their destroy [UCDA: URL. 2].*

Meanwhile, research trials in Australia have shown that where there are only minor infestations, natural predators and the disease (*Verticillium)* usually keep populations under control. Farmers and scientists disagree on whether shade reduces pest and fungal attacks on coffee. Nataraj *et al.* (1975) showed an inverse relationship between percent shade and the incidence of brown-eye-spot disease (*Cercospora coffeicola* B.).

A traditional coffee farm under shade is virtually a self-sustaining ecosystem, with little or no pesticides, fungicides, irrigation, or fertilizers necessary. According to Perfecto *et al.* (1996), coffee is not one of those crops that is loaded with insect pests. In traditional coffee plantations, predation by birds, spiders, ants, and wasps helps keeping insect pests in check.

Coffee under intercropping plantations is rarely attacked by coffee stem borers in comparison with one in mono-plantations. Some people have argued that plant diversity helped shade-coffee remain relatively free of attack, although, many pests may live there. In contrast, the relatively high humidity associated with shade may encourage fungal infection (Nghi *et al.*, 1996).

2.8 High biodiversity in intercropping farms

Concern has recently emerged about the inability of mono-coffee plantations to sustain native fauna and flora above and under ground. Without the food and shelter that shade trees can provide, many organisms do not want to live in coffee plantations.

Intercropping plantations typically support many species that provide a different canopy (Moguel *et al.,* 1999). Biotic diversity is vastly greater in intercropping than monocropping plantations. Intercropping coffee farms are the habitats for many fauna species, not only for small ones under ground but also for all ones above ground, including the bird species. Perfecto *et al.* (1995) noticed more foraging ants, and Perfecto *et al.* (1997) recorded more beetles, ants and non-formicid hymenopterans in polyculture systems. Wunderle *et al.* (1998) witnessed fewer birds foraging in monoculture than intercropping plantations.

Greenberg *et al*. (1997) observed more bird species in intercropped sites and that those birds resided in the over canopy. Reviews by Perfecto *et al*. (1996) and Moguel *et al.* (1999) contain additional information about biodiversity in coffee plantations.

2.9 Yield of each tree crop and total yield

Higher yields, more than any other factor, justify the choice to grow sun coffee. Shade trees reduce production because they intercept significant amounts of photosynthetically active radiation. Older cultivars of coffee tolerated direct sunlight poorly; the consequences included overbearing, dieback, soil exhaustion, and shortened life. Intensive breeding programs prompted by this behavior resulted in sun tolerant varieties that also require more fertilizer.

Several authors reported that tree removal increased yields in Puerto Rico (Vicente-Chandler *et al.,* 1968). Njoroge *et al.* (1995) generally found that intercropping with 12 annual food crops lowered coffee yields. In contrast, Baggio *et al.* (1997) reported greater yields with intercropping coffee, possibly because intercropped trees moderate microclimate.

These variable performances suggest that yield was strongly influenced by growing conditions. When environments were ideal (e.g. temperature, humidity, and water availability), sun coffee produced more berries (Amoah *et al.*, 1996; Beer *et al.*, 1998). However, coffee grown in mixed culture tolerated in severe conditions of the weather better.

Intercropping coffee farms not only provide a diversity of wildlife habitat, but also benefit farmers economically by providing a variety of products for local consumption and for sale. Avocados, tangerines, rubber latex, and timber offer another source of income for traditional coffee farmers and a bit of insurance during lean times, such as when coffee prices were low (Willey, 1979).

2.10 Some models of coffee intercopping system

The experience in coffee production in India showed that coffee planted under shade that had had a longer lifecycle than mono-coffee farm. It can give benefit and

stable yield for 60-80 years (Wrigley, 1988). A research result of coffee in Karnataka (India) has come up a conclusion of benefit from the intercropping coffee with orange trees or pepper, is higher than sun farms.

Intercroping of coffee with oak trees as the living support to pepper vein has brought to growers so high income, because of diversification of farm products, and stability of yields on farm. In some regions, which are often affected by storm wind, planting coffee understory of coconut trees (*Cocos nucifera* L.) could reduce damage and increase income of the growers (FAO, 1995).

Rubber-coffee-pineapple intercropping was the best model for income generation to support for rubber production during a unproductive stage. That has been conducted in some regions in China. Pineapple was harvested from the second year and lasted for five years. Four and seven years after planting, the coffee and rubber could be harvested and tapped respectively. At the present time, the intercropping of the three plants has formed a profitable system (Zheng *et al.*, 2000).

The necessity of on-farm research to assess the relationship between shade ecological features and yields has been broadly recognized. On this basis, a more sustainable coffee system could be developed, with better conservation of natural resources. The intercropping with overstory tree cover had a positive effect between 23 and 38 percent shade cover and yield was then maintained up to 48 percent. Production may decrease under shade cover more than 50 percent (Soto-Pinto *et al.*, 2000).

2.11 Fluctuation of coffee price

Coffee trees are highly vulnerable to frost and shortage of rainfall which significantly increase the incidence of infectious diseases, and drought that can wipe out entire plantations. As new trees take about three to five years before they are productive, coffee production is subject to large supply shocks. As a result, world coffee prices are highly volatile, with cycles of boom and bust being sustained over half a decade or longer [de Fontenay *et al.*: URL. 3].

Figure 2 shows robusta coffee prices on the world coffee market for the more than three decades between 1970 and 2002. One measure of price volatility, the coefficient of variation, shows a variability of some 45 percent in prices from year to year. Even the variability within each year (the intra-year variation) shows an average of 13.5 percent [de Fontenay *et al.*: URL. 3]. The coffee price has been on the way of reduction since 1977. Especially, the nosediving coffee price caused by oversupply on the world market was forecast to continue in some coming years. With this price, the coffee growers incur a loss of income, because cost of production is over gross return (DakLak Trade and Tourist Department, 2002).

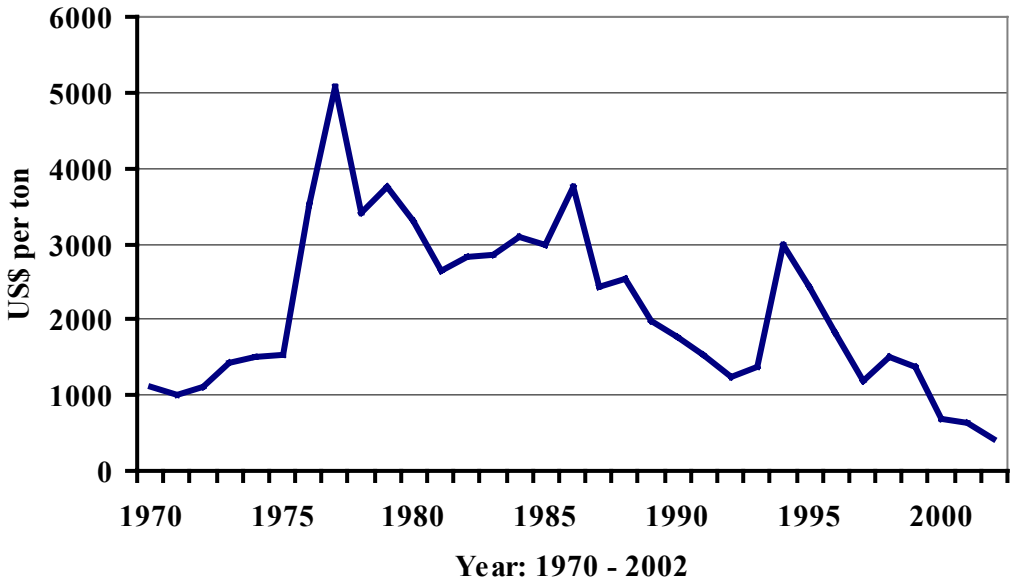

Figure 2. Robusta coffee price from 1970 to 2002
Source: de Fontenay *et al.*: URL. 3.
DakLak Trade and Tourist Department, 2002.